NSTS - 08353

STS-32 NATIONAL SPACE TRANSPORTATION SYSTEM MISSION REPORT

February 1990

NASA
National Aeronautics and Space Administration

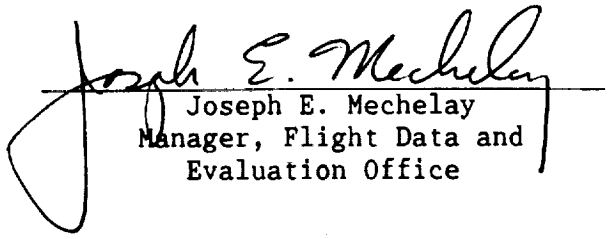
Lyndon B. Johnson Space Center
Houston, Texas

NSTS-08353

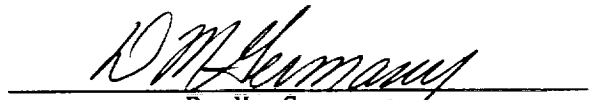
STS-32

NATIONAL SPACE TRANSPORTATION SYSTEM

MISSION REPORT



Joseph E. Mechelay
Manager, Flight Data and
Evaluation Office



D. M. Germany
Manager, Orbiter and GFE Projects

Leonard S. Nicholson
Deputy Director, National STS Program

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS 77058

February 1990

INTRODUCTION

The STS-32 National Space Transportation System (NSTS) Mission Report contains a summary of the vehicle subsystem activities on this thirty-third flight of the Space Shuttle and the ninth flight of the OV-102 Orbiter vehicle (Columbia). In addition to the Discovery vehicle, the flight vehicle consisted of an External Tank (ET) (designated as ET-32/LWT-25), three Space Shuttle main engines (SSME's) (serial numbers 2024, 2022, and 2028), and two Solid Rocket Boosters (SRB's) (designated as BI-035).

The primary objective of this flight was to successfully deploy the SYNCOM IV-F5 satellite and to retrieve the Long Duration Exposure Facility (LDEF) satellite, which had been placed in orbit on April 6, 1984, by the STS-41C mission. The secondary objective of this flight was to perform all operations necessary to support the secondary payloads. In addition, 21 development test objectives and 14 detailed supplementary objectives were assigned to this flight.

The sequence of events for this mission is shown in Table I. The report also summarizes the significant problems that occurred in the Orbiter subsystems during the mission, and the official problem tracking list is presented in Table II. In addition, each of the Orbiter problems is cited in the subsystem discussion within the body of the report.

The crew for this thirty-third flight of the Space Shuttle was Daniel C. Brandenstein, Capt., USN, Commander; James D Wetherbee, Lt. Cdr., USN, Pilot; Bonnie J. Dunbar, Ph.D., Mission Specialist 1; Marsha S. Ivins, Mission Specialist 2; and G. David Low, Mission Specialist 3. This was the third flight for the Commander, the second flight for Mission Specialist 1, and the first flight for the remaining three crew members.

MISSION SUMMARY

The STS-32 mission was originally scheduled for launch on December 18, 1989; however, problems in preparing launch pad 39A resulted in delaying the mission until January 8, 1990. The countdown for a January 8, 1990, launch of STS-32 proceeded nominally until the planned T-9 minute hold. The normal hold-time at T-9 minutes was lengthened because of unsatisfactory weather conditions in the Return to Launch Site (RTLS) landing area. In a further attempt to launch during the 58-minute window, the countdown was resumed until T-5 minutes where it was held; however, the weather did not improve and the launch was scrubbed until January 9, 1990.

A review of flight crew equipment from the scrubbed launch attempt showed that a clamp had failed and the two guide rods were bent severely on the Mission Specialist-3 (MS-3) light. The clamp assembly was repaired and re-installed.

The launch countdown proceeded nominally for the launch on January 9, 1990. The vehicle was launched as planned at 09:12:35:00.017 G.m.t. (06:35 a.m. c.s.t.) on an inclination of 28.5 degrees after a flawless countdown with no unplanned holds. SSME and SRB ignitions occurred as expected and the launch and ascent phase performance was satisfactory in all respects. Main engine cutoff (MECO) occurred approximately 512.2 seconds after lift-off. Overall Orbiter subsystems operation during ascent was nominal, although a number of minor problems were noted. None of the problems had any effect on ascent or subsequent mission operations.

During ascent, the auxiliary power unit (APU) 3 lubrication oil outlet pressure rose to 90 psi; however, the pressure began decreasing about 9 minutes after lift-off, and reached the normal range prior to APU 3 shutdown. A similar anomalous signature was observed on another APU during the STS-33 mission. Also, the APU 1 injector temperature was high during ascent, but the condition did not affect mission operations. In addition, the APU 3 exhaust gas temperature (EGT) 2 operated erratically. Anomalous operation of EGT sensors has been noted on previous missions.

Data downlinked through the FM 1 transmitter were lost for about 5 seconds when the FM 1 transmitter power output dropped to zero watts at 09:12:35:02.7 G.m.t. The crew switched to the FM 2 transmitter and the FM downlink was restored. The FM 1 transmitter was switched on later during the first day and it did not operate, confirming a failure in that system.

A direct-insertion ascent trajectory was flown; therefore, no OMS-1 maneuver was planned. The OMS-2 maneuver was satisfactorily performed with a differential velocity of 218.5 ft/sec. The right OMS helium tank pressure P2 measurement indicated off-scale low for a short period of time at the beginning of the maneuver. This did not affect the maneuver as the P1 measurement indicated properly. After the OMS-2 maneuver, the reading returned to normal.

The SYNCOM IV-F5 payload was nominally deployed at 10:13:18:39 G.m.t. A successful perigee kick motor (PKM) burn was completed 45 minutes later, followed by six successful liquid apogee motor burns. The satellite checkout and activation were nearing completion at the time of this writing.

The OMS performed nominally during all five LDEF rendezvous maneuvers. Propellant system repressurization was performed using the helium A regulators on both pods for all maneuvers.

The text and graphics system (TAGS) did not initially respond to the uplink image signal through the Ku-band forward link due to a ground problem. The ground problems were cleared and the TAGS responded properly. The TAGS hard-copier experienced numerous paper jams until flight day 5 when an in-flight maintenance (IFM) procedure was implemented by the crew, and TAGS operation was satisfactory with no jams after that time.

While performing the remote manipulator system (RMS) checkout, the crew and ground controllers observed brake-slip fault summary messages when the RMS

was cradled. Also, a minor anomaly occurred twice during RMS operations when an audible tone was activated with no associated annunciator lights.

At approximately 10:10:12 G.m.t., hydraulic accumulator 1 pressure dropped to 1950 psia, and the system initiated a recharge via the circulation pump. A second recharge was initiated at approximately 10:16:29 G.m.t. Leak rates of unloader valve 1 were calculated for the time periods preceding these recharges, and the leak rates exceeded specifications. Sufficient consumables were available to maintain constant circulation pump operation on one system, if required.

At 11:08:58 G.m.t., the crew reported free water in the vicinity of humidity separator B. The crew attached a fiber scope to the closed circuit television (CCTV) camera and downlinked the video which was used to verify the water flow problem. The crew switched to humidity separator A, and the free water cleanup IFM procedure was initiated.

During orbit 28, while communications were established through Tracking and Data Relay Satellite (TDRS)-West, the S-Band system lost forward link lock. There appeared to be no discernible signal within the range of the S-Band transponder sweep. After approximately 10.5 minutes, the transponder re-established lock and performed nominally.

The RMS was used to perform an external survey of the Orbiter. A piece of RTV tile repair was found during the postlaunch beach walk down. The RTV was identified as coming from the tip of the right outboard elevon. The elevon was viewed with the RMS elbow camera, and a confirmation was given by the ground that this condition would cause no problem for this mission.

Rendezvous operations with the LDEF were successfully performed as planned. Proximity operations were concluded with LDEF grapple occurring at 12:15:16:05 G.m.t. A photographic survey of the LDEF and its subsequent berthing in the payload bay was completed very satisfactorily.

The crew reported a hairline crack at one end of the fluids experiment apparatus (FEA) ampule 4. An in-flight maintenance procedure was performed and ampule 4 was removed and stowed, and FEA operations were re-initiated.

On orbit 71, a 9-minute loss of the S-band link occurred during switching from the lower left aft antenna to the lower right aft antenna. A loss of communication (no uplink) also occurred during the last half of orbit 87 beginning at approximately 15:00:12 G.m.t. Neither of these losses significantly affected the mission.

The crew reported seeing about one cup of water at the humidity separator A air outlet at 14:19:16 G.m.t., and at 16:04:48:00 G.m.t. The crew implemented cleanup procedures.

At 15:01:37:17 G.m.t., a sudden bias shift in the inertial measurement unit (IMU) 1 -Y axis accelerometer was detected. Subsequently, 7 separate shifts occurred within a 10-minute period, during which RM software deselected IMU 1.

Following this incident, IMU 1 performed nominally and at 15:05:35 G.m.t., it was reselected and realigned by the crew, and the IMU operated satisfactorily for the remainder of the mission.

The RMS was uncradled at 15:14:01:00 G.m.t. and a direct drive test was performed. The exterior survey of the Orbiter was performed with no RMS or Orbiter problems noted.

Water spray boiler (WSB) 2 and 3 regulator outlet pressure decay rates decreased during the early part of the mission. The pressure decrease was within specification over the span of the mission.

At approximately 16:15:58 G.m.t., the FEA center front wall temperature sensor indicated that the wall exceeded the touch temperature limit of 113° F. The FEA deactivated itself as designed; however, the crew reported that the surface was not hot. The system was turned off for the remainder of the day.

On orbit 111, during the TDRS-West pass, the Ku-band indicated good forward link, but the return link could not be established. After several attempts to acquire the signal, the Ku-band handed over to TDRS-East and provided good return link throughout the entire pass. Again on the orbit 112 TDRS-West pass, the return link was not obtained.

The avionics bay 3A smoke detector A alarm sounded on a number of occasions. Data review indicated no anomalous smoke concentrations were present. The smoke detector circuit breaker was opened on flight day 10 and remained open for the remainder of the mission.

At 17:23:46:51 G.m.t. during a sleep period, a state vector update was commanded by the ground just prior to loss of signal. The state vector was corrupted and the Orbiter began executing a multi-axis rotation at 3 deg/sec with a number of thrusters firing. The rotation continued until the acquisition of signal period when the crew was awakened and instructed to switch to manual DAP to arrest the unwanted rates. A good state vector was then uplinked and no further problems occurred.

Two attempts were unsuccessful late in the mission in cleaning up water leaking from humidity separator A using the free fluid disposal IFM procedure. No suction was detected at the nozzle indicating possible blockage in the line or nozzle. A RMS survey of the dump nozzle indicated no ice formation.

A waste water dump was attempted at 018:13:29:00 G.m.t., but waste water did not decrease and an abnormal waste water nozzle temperature signature was observed. The nozzle heat-up signatures, dump valve responses, and waste water dump line temperatures appeared to be normal. Blockage of the waste water dump line was suspected. As a result, no waste water dumps were performed for the remainder of the mission. This condition did not impact mission operations as sufficient ullage capacity existed in the waste tank.

The flight control system (FCS) checkout was performed using auxiliary power unit (APU) 1, which ran for 6 minutes 18 seconds. Hydraulics as well as APU performance during the FCS checkout was nominal.

The STS-32 landing was postponed approximately 24 hours because of unacceptable weather (fog) at the primary landing site, Edwards Air Force Base, CA. Also, the weather conditions were unacceptable for landing at Northrup and KSC.

While making final checks for the deorbit maneuver and entry, general purpose computer (GPC) 5 in which the backup flight system (BFS) software was resident registered illegal engage input/output term B. As a result, the BFS was loaded into GPC 2 and reinitialized. The GPC set was restrung and GPC 5 was powered off for the remainder of the mission. This problem resulted in the deorbit maneuver, entry and landing being delayed one revolution.

After completion of all final entry preparations, including stowage and payload bay door closure, the OMS deorbit maneuver was performed at 20:08:30:22 G.m.t., with a firing duration of 299.5 seconds and a differential velocity of 489.7 ft/sec. The deorbit maneuver had an out-of-plane component of 51 degrees and had the longest firing time of any OMS maneuver during the Shuttle flight program. Following the deorbit maneuver, data indicated that the APU 2 EGT 2 and APU 3 EGT 2 sensors were operating erratically. The erratic operation of EGT sensors has been noted on previous missions and does not affect mission operations.

Entry interface occurred at 020:09:04:26 G.m.t. The normal entry blackout period did not occur as communications were maintained through the TDRS-West satellite. Abnormal water spray boiler (WSB) 3 operation led to a switchover to controller B and normal operation resumed. WSB 3 switched to the heat exchanger (HX) mode of operation early, at 114 °F instead of 180 °F. Neither of these conditions affected entry operations. Main landing gear touchdown occurred at 020:09:35:35 G.m.t. on concrete runway 22 at Edwards Air Force Base, CA. Nose landing gear touchdown followed 16 seconds later with wheels stop at 020:09:36:39 G.m.t. The landing and rollout of the heaviest Orbiter at landing (228,335 lb) were normal in all respects. The APU's were shut down at 020:09:52:56 G.m.t., and the crew completed their required postflight reconfigurations and egressed the vehicle, ending an extremely successful as well as the longest mission (10 days, 21 hours, 1 minute 39 seconds) of the Space Shuttle Program.

Eight middeck payloads were flown on this mission. The FEA completed approximately 85 percent of the assigned objectives. A temporary power loss occurred on the protein crystal growth (PCG) and the 4 °C sample may have been ruined, but the 22 °C sample should provide data. All IMAX camera film was exposed, but only 83 percent of the objectives were met because bad weather precluded photography of some sites. All 100 percent of the objectives of the mesoscale lightning experiment (MLE) and the latitude/longitude locator (LLL) experiment were met. Initial indications are that 100 percent of the established goals for the characterization of neurospora circadian rhythms (CNCR) experiment were achieved. The Air Force Maui Optical Site calibration test (AMOS) failed to meet any of its objectives because of bad weather over the

ground observation site. Over 100 percent of the American flight endocardiograph (AFE) experiment objectives were met in that all five of the crew members participated in the experiment, whereas scans were required on only two of the crew members.

Twenty-one development test objectives (DTO's) were scheduled for this flight. Initial indications show that only two of the DTO's were not completed - one because the DTO is no longer active and the other required prelaunch measurements that were not taken. Preliminary data indicate that all 14 of the detailed supplementary objectives (DSO's) were accomplished successfully.

SOLID ROCKET BOOSTERS

All SRB systems performed as expected. The SRB prelaunch countdown was normal. Solid rocket motor (SRM) propulsion performance was well within the required specification limits, and propellant burn rates for both SRM's were near normal. SRM thrust differentials during the buildup, steady state, and tailoff phases were well within specifications. All SRB thrust vector control (TVC) prelaunch conditions and flight performance requirements were met with ample margins. No SRB or SRM launch commit criteria (LCC) or Operations and Maintenance Requirements and Specification Document (OMRSD) violations occurred.

Power-up of the SRM joint protection heaters was accomplished routinely. All joint, igniter, and case temperatures were maintained within acceptable limits throughout the countdown. Ground purges maintained the nozzle-bearing and flex-boot temperatures within the required LCC ranges.

The flight performance of both SRM's was very close to preflight predictions and well within the allowable performance envelopes. The SRB flight structural temperature response was as expected. Postflight inspection of the recovered hardware indicated that the SRB thermal protection system (TPS) performed properly during ascent with very little TPS acreage ablation.

Separation subsystem performance was entirely normal with all booster separation motors expended and all separation bolts severed. Nose-cap jettison, frustum separation, and nozzle jettison occurred normally on each SRB.

The entry and deceleration sequence was properly performed on both SRB's. The parachute deployments were successful, and all drogue and main parachutes were recovered.

During the postflight inspection of the SRB's, the right SRM safe-and-arm gasket had a small depression in the crown of the secondary seal aft face. The crown of the seal was depressed inward at the 0-degree location and the depression measured 0.050-inch circumferentially by 0.026-inch radially by 0.0025-inch deep.

During the postflight inspection, both the left and right SRB's were missing some of their EPDM and Q3-6077 materials from the upper strut. A 5-inch section

of EPDM was missing from the right SRB, and a 4-inch section was missing from the left SRB. The PR-855 silicone foam was missing below the lost EPDM on both SRB's. Also, some heat discoloration was noted on the outer wrapping of two electrical cables, and five sealant caps were eroded.

The postflight inspection revealed that six Hi-lok fasteners on the left SRB External Tank attachment (ETA) ring were protruding into the ETA ring cover for the aft integrated electronics assembly, and minor sooting was also found on a small area of the cover.

The postflight assessment of the right SRM igniter inner gasket revealed raised areas of rubber along both sides of the gasket on the outer primary seals. The condition was limited to the void and cushion areas (non-sealing surfaces) intermittently around the circumference of the outer primary seals. The largest area found was 0.020-inch circumferentially.

The postflight disassembly process revealed a broken fastener on the left SRB upper strut fairing (milk-can). Initial indications are that the failure occurred because of torsional loads, which are not present in the flight or water impact environments. As a result, the failure appears to have occurred during the assembly process at KSC prior to launch.

EXTERNAL TANK

All objectives and requirements associated with the ET loading and flight operations were met. All ET electrical equipment and instrumentation performed satisfactorily. The operation of the ET heaters and purges was monitored and all performed properly. There were no LCC or OMRSD violations identified.

As expected, only the normal ice/frost formations for the January environment were observed during the countdown. There was no ice on the acreage areas of the ET. A debonded area of a 2-inch plug was observed on the liquid hydrogen tank aft dome apex; however, previous vehicles have flown with debonded plugs in the same area. The ice/frost Red Team reported that the liquid oxygen and liquid hydrogen tanks had a considerable amount of condensate. Normal ice/frost was observed on the liquid oxygen and liquid hydrogen feed lines, feed line brackets and pressure line brackets. No violations of the ice/frost criteria were found.

The ET pressurization system functioned properly throughout engine start and flight. The minimum liquid oxygen ullage pressure experienced during the period of the ullage pressure slump was 15.4 psig.

The ET tumble system was deactivated for this flight. ET separation was normal and ET entry and breakup occurred within the predicted footprint.

A review of the ET photography from the umbilical well camera revealed an unusual TPS pattern (18 inch by 24 inch) as missing insulation from the left

forward bipod strut attachment point on the intertank. The unusual pattern was identified as four divots of about 18 to 24 inches in diameter and one divot that was 6 inches in diameter.

SPACE SHUTTLE MAIN ENGINES

All SSME parameters appeared to be normal throughout the prelaunch countdown and compared well with the prelaunch parameters observed on previous flights. Engine ready was achieved at the proper time, and all LCC were met.

Flight data indicate that SSME performance at main engine start, thrust buildup, mainstage, shutdown and during propellant dumping operations was well within specifications. All three engines started and operated normally. High pressure oxidizer turbopump and high pressure fuel turbopump temperatures were normal throughout the period of engine operation. The SSME controllers provided proper control of the engine throughout the flight. Engine dynamic data generally compared well with previous flight and test data. All on-orbit activities associated with the SSME's were accomplished successfully.

The postflight inspection revealed a 5/64-inch diameter debonded area on the main engine 2 main combustion chamber. The debonded area was located in the aft region between adjacent feedslots and in line with nozzle tube 664. This problem is similar to, but not as severe - no leak was present - as the debonded area found after the STS-29 mission. This STS-32 engine has experienced 16 starts and 4650 seconds of hot-fire time. Current data from non-destructive tests indicates that the propagation rate is slow and stable, and a low probability exists for a massive bondline failure.

The postflight inspection also revealed two gouges in main combustion chambers. One was 2-inches long by 0.080-inch wide by 0.0009-inch deep with raised metal about 0.030-inch high and was located in main engine 3 (no. 2028) about 2 inches from the throat area at the 6 o'clock position. The second gouge was 0.250-inch long by 0.024-inch wide by 0.010-inch deep and was located in main engine 1 (no. 2024) about 6 inches from the throat area at the 6 o'clock position.

SHUTTLE RANGE SAFETY SYSTEM

Shuttle range safety system (SRSS) closed-loop testing was completed as scheduled at approximately T-45 minutes in the launch countdown. The SRSS safe and arm devices were armed at T-5 minutes and all system inhibits were turned off at T-10 seconds as planned. All SRSS measurements indicated that the system performed as expected throughout the flight. The system signal strength remained above the specified minimum (-97 dBm) for the duration of the flight.

Prior to SRB separation, the SRB safe-and-arm devices were safed and SRB system power was turned off as planned. The ET system remained active until ET separation from the Orbiter, as required.

ORBITER PERFORMANCE

MAIN PROPULSION SYSTEM

The overall performance of the main propulsion system (MPS) was excellent. As a result of a procedural error that occurred during liquid oxygen chilldown, the ET liquid oxygen vent valve was incorrectly closed for approximately 13 1/2 minutes. The vent valve was opened shortly after the procedural error was found, and this condition did not affect the hardware or the loading accuracy. Liquid oxygen and liquid hydrogen loading was performed as planned with only one liquid hydrogen stop flow/revert. The stop flow was conducted during replenish to allow the leaking liquid hydrogen replenish valve to be retorqued. The leak was stopped and replenish was re-established. The total elapsed time from the start of the stop flow until the liquid hydrogen level was replenished to 100 percent was approximately 1 hour 24 minutes. This stop flow had no significant effect on the liquid hydrogen load at engine start.

Throughout the preflight operations, no significant hazardous gas concentration was detected, and the maximum hydrogen level in the Orbiter aft compartment was 200 ppm, which compares well with previous data for this vehicle.

The calculated liquid hydrogen load at the end of replenish was about 100 lbm more than the inventory load. The calculated liquid oxygen load at the end of replenish was about 80 lbm more than the inventory load. This represents an estimated loading accuracy of 0.04 percent and 0.005 percent for the liquid hydrogen and oxygen, respectively.

Ascent MPS performance appeared to be completely normal. Preliminary data indicate that both pressurization systems performed as predicted throughout the flight. This flight marked the fifth time that the prepressurization of the liquid oxygen tank was intentionally reduced 2 psi (trip level reduced from 20.5 psig to 18.5 psig) to prevent closing the gaseous oxygen flow control valves during the engine start transient. The minimum liquid oxygen ullage pressure experienced during the period of the ullage pressure slump was 15.4 psig.

Data showed that the gaseous oxygen flow control valve on SSME 2 was slow in opening on its first de-energization cycle at lift-off plus 61 seconds (Flight Problem STS-32-06). The valve required 0.75 second to open and the specification requirement is 0.2 to 0.4 second. All other engine 2 flow control valve cycles were nominal.

Trajectory reconstruction indicates that the vehicle specific impulse was near the MPS assessment tag values. Ullage pressures were maintained within the required limits throughout the flight. Feed system performance was normal, and liquid oxygen and hydrogen propellant conditions were within specified limits during all phases of the flight. All net positive suction pressure (NPSP) requirements were met. Propellant dump and vacuum inerting were accomplished satisfactorily.

During postlanding operations at Dryden Flight Research Facility, a reverse blowing leak from the liquid hydrogen outboard fill and drain relief valve was found (Flight Problem STS-32-25). The relief valve relieves from an outboard pressure to a lower pressure in the line segment between the outboard and inboard fill and drain valves. No operational necessity exists for this relief valve on the outboard fill and drain valves, except for simplicity and commonality in manufacturing.

REACTION CONTROL SUBSYSTEM

Performance of the reaction control subsystem (RCS) was nominal in all respects. A total of 5055.7 lb of propellant was used during the mission, including the RCS forward dump burn to zero percent during entry. This total also includes propellant from the orbital maneuvering subsystem (OMS) used during interconnect operations. Vernier thruster F5R was fired continuously for over 195 seconds during the multi-axis maneuver that occurred as a result of the improper state vector that was incorporated into the guidance system. This firing time exceeds the certification limit for this class of thruster, but it is not considered a problem because of firings well beyond this value (1500 seconds) in qualification tests at White Sands Test Facility.

Vernier thruster F5L had a slightly lower chamber pressure during a firing, Certain vernier thrusters have intermittently shown during previous missions lower chamber pressures during short firings and sluggish pressure rise during long firings. Particle buildup in the chamber pressure sensor tube is suspected.

ORBITAL MANEUVERING SUBSYSTEM

The OMS performance was satisfactory throughout the mission with seven firings being performed including the 299.5-second deorbit maneuver which is the longest firing time experienced during the Shuttle flight program. Five of the maneuvers were performed with a single engine and in support of the rendezvous with the LDEF. A total of 13010 lb of oxidizer and 7839 lb of fuel was used during the seven maneuvers.

An LCC paragraph 6.4-05 violation occurred during the scrubbed launch countdown on January 8, 1990, when the right-hand OMS tank pressure differential exceeded the 15-psid limit. This pressure differential resulted from temperature variations that caused a slight pressure increase because of the small ullage volume, and differential helium absorption which resulted in lower than normal pressure. The system was repressurized and this brought the pressure differential within the LCC limits.

The right OMS engine yaw actuator no-back device allowed the engine to move 0.112 degree during ascent, and this amount exceeds the specification limit of 0.1 degree (Flight Problem STS-32-04). Measurements taken during entry indicated satisfactory operation of the device. The actuator remained selected for the entire mission and operated satisfactorily.

Two transducer problems occurred concerning helium and ullage pressures. The right-hand OMS helium pressure 2 indication went off-scale low at the start of the OMS-2 maneuver and recovered following the maneuver (Flight Problem STS-32-03a), and operated nominally for the remainder of the mission. The right-hand OMS fuel tank ullage pressure indication was erratic, varying intermittently from 4 to 10 psi (Flight Problem STS-32-03e). This pressure indication exhibited the same behavior during the STS-28 mission.

POWER REACTANT STORAGE AND DISTRIBUTION

The power reactant storage and distribution (PRSD) subsystem performed in a nominal manner throughout the mission. A total of 2560.2 lb (loaded - 3926 lb) of oxygen and 308.1 lb (loaded - 471.8 lb) of hydrogen were used from the five tank sets contained on this vehicle. Breathing oxygen for the crew consumed 113.9 lb of this total. Power reactants remaining at landing were adequate to support a 97-hour extension at the average power level of 13.7 kW.

FUEL CELL POWERPLANT SUBSYSTEM

The fuel cell powerplant subsystem performed satisfactorily and fulfilled all electrical requirements for the mission. The average electrical power level was 13.7 kW and the total Orbiter load averaged 442 amperes with the fuel cells producing 3565 kWh of electrical energy and 2754.4 lb of water. No new anomalies occurred during the mission; however, the fuel cell 1 flow meter operated erratically throughout the mission. This anomaly had been identified on STS-28, and was not corrected because loss of this meter would not affect the mission.

AUXILIARY POWER UNIT SUBSYSTEM

The auxiliary power unit (APU) subsystem performed satisfactorily with the exception of four in-flight anomalies that were noted, but did not affect the mission.

APU 1 operated for 1 hour 26 minutes 57 seconds; APU 2 operated for 1 hour 46 minutes 46 seconds; and APU 3 operated for 1 hour 20 minutes 40 seconds. A total of 578 lb of fuel were consumed during the 4 hours 34 minutes 23 seconds of operation. The APU's were operated for 17 minutes 19 seconds after landing.

APU no.	Ascent		FCS Checkout		Entry		Total	
	Run time, min:sec	Consumption, lb	Run time, min:sec	Consumption, lb	Run time, min:sec	Consumption, lb	Run time, min:sec	Consumption, lb
1	19:21	49	06:20	16.0	61:16	121	86:57	186
2	19:21	49	00:00	0.0	87:25	153	106:46	202
3	19:22	55	00:00	0.0	61:18	135	80:40	190
	58:04	153	06:20	16.0	209:59	409	274:23	578

Three of the four anomalies that have been identified involve instrumentation for monitoring APU operation. The non-instrumentation anomaly concerns the APU

3 high lubrication oil outlet pressure during ascent (Flight Problem STS-32-02). The pressure began increasing about 4 minutes after APU start and leveled out at 80 to 90 psia where it remained for about 6 minutes before decreasing to the nominal range of 50 to 60 psia. This scenario is indicative of hydrazine in the gearbox forming wax with the lubrication oil that is melted once the lubrication oil temperature is high enough to melt the wax (225 °F) at which point the oil outlet pressure returns to normal. APU 3 exhaust gas temperature (EGT) sensor 2 failed during ascent (Flight Problem STS-32-03b). APU 2 injector temperature measurement indicated about 50 °F above gas generator bed temperature during heater cycling (Flight Problem STS-32-03d). APU 2 EGT 2 sensor failed during entry (Flight Problem STS-32-03g). None of these anomalies had any affect on the mission.

APU 1 injector tube temperature was about 140 °F higher than APU's 2 and 3 during ascent and descent. This same behavior was observed on STS-28. The temperature peaked at 1420 °F. A review of the acceptance test data indicates that a high injector tube temperature is characteristic of this APU and is the result of the physical location of the sensor within the injector well.

HYDRAULICS/WATER SPRAY BOILER SUBSYSTEM

The hydraulics/water spray boiler (WSB) subsystem operated satisfactorily during the mission, in that all requirements placed upon the subsystem were met. During the prelaunch operations for the scrubbed launch attempt on January 8, 1990, the hydraulic system 2 unloader valve demonstrated leakage greater than that allowed by the preflight waiver. After circulation pump shutdown, the system 2 bootstrap pressure decayed until the accumulator piston bottomed out at approximately 1750 psia (Flight Problem STS-32-16). This condition is indicative of contamination in the high ball area of the valve. All three valves operated satisfactorily during the launch on January 9, indicating that the contamination had cleared from the high ball area of unloader valve 2. However, during day 4 of the mission, the hydraulic system 1 accumulator 1 was recharged multiple times during a 10-hour period, indicating increased leakage in the high ball area of the unloader valve (Flight Problem STS-32-16). This pressure loss is attributed to contamination because continuous circulation pump 1 operation was initiated for a 4-hour period and during that time, the accumulator 1 recharged, and the pressure remained steady for the remainder of the mission. MPS thrust vector controller (TVC) isolation valve 1 was opened during the circulation pump 1 operation in an unsuccessful attempt to restow SSME 1 engine with hydraulic pressure.

The WSB 2 and 3 gaseous nitrogen regulator outlet pressures decayed throughout the mission to levels of 16.2 and 14.7 psia prior to entry, indicating either a gaseous nitrogen or a water leak (Flight Problem STS-32-17). The decay rate was calculated several times during the 11-day mission, and the rate was within the specification limit of no more than 0.6 psi/hr. Also, the consumable redline of 13.5 psia was not exceeded. This condition did not affect mission operations.

At approximately 020:09:13:00 G.m.t., WSB 3 experienced a high-core temperature increase with a corresponding switch to the heat exchanger mode of operation

(Flight Problem STS-32-23). Reservoir temperature for hydraulic system 3 was approximately 114 °F when the switchover occurred (normally, 183 °F is switchover temperature with full heat exchanger mode operation at 208 °F), causing over cooling of APU 3 lubrication oil to occur. The system was switched to the B controller and normal operation resumed.

PYROTECHNICS SUBSYSTEM

The pyrotechnics subsystem operated satisfactorily except for the pyrotechnics associated with the three bottles in the Orbiter port-side gas sampler system assembly located on the 50-1 access door. No gas samples were collected because none of the pyrotechnics fired to open the bottles (Flight Problem STS-32-29). This equipment will be shipped to JSC for troubleshooting. The starboard side gas sampler system assembly performed normally.

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM

The performance of the environmental control and life support subsystem (ECLSS) was acceptable, although some minor problems occurred. None of these problems impacted the successful completion of the planned mission.

The humidity separator B had water carry-over (Flight Problem STS-32-07a), and the crew switched to humidity separator A at 1 day 20 hours 34 minutes mission elapsed time (MET). The crew reported seeing about one cup of water at the humidity separator A air outlet shortly after the pre-sleep lithium hydroxide (LiOH) canister changeout at 14:19:16 G.m.t. (Flight Problem STS-32-07b). The water tanks were depressurized for the remainder of the mission except for water dumps. The crew reported no visible water during the following post-sleep LiOH canister changeout. Approximately 2 cups of water were found prior to the sleep period at 16:04:48:00 G.m.t. The crew implemented cleanup procedures and performed an operational check. Humidity separator A was switched off and then on, and it took 27 seconds for the speed to return to normal. Normal speed-up time is 12 seconds. The cabin humidity was maintained within the normal range throughout the mission. The crew was able to clean up the water using the free fluid disposal IFM procedure until the waste water dump nozzle became blocked late in the mission. After that blockage, the crew used towels to clean up the water.

The flash evaporator, radiators, and ammonia boiler subsystems operation was nominal, although an instrumentation problem and a failed heater were noted. Premission analyses showed that the LDEF would affect the coldsoak attained prior to entry, causing ammonia boiler activation before landing. However, indications are that the LDEF reached a lower surface temperature than predicted during the pre-entry coldsoak periods because ammonia boiler activation was not required until 13 minutes after landing.

Throughout the mission, the flash evaporator system (FES) loop 2 evaporator outlet temperature indication lagged the loop 1 temperature significantly during thermal transients, indicating a partially debonded sensor (Flight Problem STS-32-03c). During flight day 5 activities, the topping aft duct temperature

never exceeded 38 °F after the B heater was turned on, indicating a failed heater string (Flight Problem STS-32-14). Topping duct systems A and C heaters performed nominally.

Fourteen supply water dumps were successfully completed and three waste water dumps were attempted, two of which were successfully completed. The waste water dump nozzle became blocked late in the mission (most likely from debris collected during the free fluid disposal IFM), and a free fluid disposal IFM was unsuccessful as well as a waste water dump (Flight Problem STS-32-21). In addition, an instrumentation problem concerning the erratic quantity reading for the supply water tank B was noted (Flight Problem STS-32-03f).

The waste collection system (WCS) operation was nominal, and in addition, the vacuum vent quick disconnect on the WCS was used to vent the lower body negative pressure device (DSO 478) as planned each time the device was used.

At 17:16:08:36 G.m.t., the avionics bay 3 smoke detector A annunciated and the alarm did not latch on (Flight Problem STS-32-19). Data review indicated no anomalous smoke concentrations were present. A retest of detectors 3A and 3B showed both to be operating within expected limits; however, the smoke detector continued to produce alarms. The smoke detector A circuit breaker was opened on flight day 10 and remained open for the remainder of the mission.

AVIONICS SUBSYSTEMS

The avionics subsystems met all requirements for the mission; however, a number of significant problems occurred within the various subsystems comprising avionics.

Inertial measurement unit (IMU) performance was nominal except for a 10-minute period beginning at 15:01:37:00 G.m.t., when the IMU redundancy management (RM) deselected IMU 1 because the velocity limit was exceeded (Flight Problem STS-32-15). During this 10-minute period, both the Y-axis velocity and inner roll outputs experienced nine distinct time-synchronized perturbations. The problem was cleared and did not reappear during IMU 1 performance for the rest of the mission.

The -Y star tracker had a pressure-failed indication that was known prior to flight and was an expected condition that did not affect mission operations. Data indicates a higher-than-average target suppression activity by both star trackers that may be indicative of light shade contamination. This condition did not affect flight operations and the light shades will be inspected during postflight turnaround activities.

At 17:23:46:51 G.m.t., a state vector update was commanded by the ground controllers just prior to loss of signal (LOS). Frame synchronization errors that apparently occurred during the uplink corrupted the state vector. The onboard two-stage buffer compare gave a correct reject indication, but the command was erroneously executed by the ground controllers. A series of GPC errors began to appear as the planned loss of signal occurred. All of the

errors were arithmetical, which is indicative of a corrupted state vector. As a result of the corrupted state vector, the Orbiter was commanded by onboard guidance into a multi-axis rotation at 3 deg/sec with a number of thrusters firing. The rotation continued until acquisition of signal when the crew was awakened and instructed to switch to manual DAP and arrest the unwanted rates, after which a new state vector was transmitted. A review of the dump data from GPC's 1 and 4 showed that the hardware and software performed correctly throughout the period of the corrupted state vector update, and the cause of the corrupted state vector update being executed was a ground controller error.

During deorbit preparations and about 15 minutes prior to the planned deorbit maneuver, GPC 5, in which the BFS software was resident, logged 43 GPC error code 41's (illegal engage/input-output (I/O) terminate B) because of the BFS detecting no I/O terminate B discrete when the engage discretes were not present (Flight Problem STS-32-22). GPC 5 was powered off and the BFS was loaded in GPC 2 and reinitialized for entry. Redundancy string 2 was assigned to GPC 4 for entry. As a result of this failure, the deorbit maneuver was delayed one revolution.

Two display and control problems were noted during the mission. The forward DAP B select switch contact A failed (Flight Problem STS-32-08). Also, the forward bulkhead payload bay floodlight failed off and repeated attempts to repower the light were unsuccessful (Flight Problem STS-32-10).

The communications and tracking subsystem supported the mission requirements, although a number of problems were noted. During ascent (about 2.7 seconds after lift-off), the FM transmitter 1 power output dropped to zero watts (Flight Problem STS-32-01). FM transmitter 2 was enabled and it worked satisfactorily.

Multiple unexplained dropouts of the S-band Tracking and Data Relay Satellite (TDRS) forward link dropouts were experienced during the flight (Flight Problem STS-32-18). The dropouts occurred an both the TDRS-East and West satellites, on both strings of the S-band system, and at both high and low frequencies. Preliminary analysis of flight data indicate that these dropouts have a signature that is different from previous S-band anomalies involving antennas and switches. No faulty line replaceable units (LRU's) have been found.

The text and graphics system (TAGS) had several jams during the first 5 days of the mission (Flight Problem STS-32-05). The jams occurred at the cutter area during imaging. This type of jam was easily accessible and cleared by the crew. To prevent another jam, the crew spooled off 15 feet of paper and re-threaded. After advancing all exposed sheets, the crew reported receiving 15 blank sheets, and normal TAGS message traffic resumed. The TAGS hardcopier continued to have a number of jams, but each one was successfully cleared. A IFM procedure was given to the crew and after it was performed, the TAGS operated satisfactorily for the remainder of the mission.

The CCTV system had a number of camera failures during the mission:

a. CCTV camera A had a spot near the center of the field of view (Flight Problem STS-32-11a).

b. CCTV camera that is located on the remote manipulator system (RMS) elbow had a failure of the color wheel (Flight Problem STS-32-11b).

c. CCTV camera C had a poor picture when used in darkness conditions (Flight Problem STS-32-11c).

d. CCTV camera D had a spot near the center of the field of view (Flight Problem STS-32-11d).

The right OMS engine yaw actuator no-back device allowed the engine to move 0.112 degree during ascent, and this amount exceeds the specification limit of 0.1 degree (Flight Problem STS-32-04). Measurements taken during entry indicated satisfactory operation of the device.

Intermittent command problems were experienced with the operations (OPS) 1 recorder. In one instance, the recorder was commanded to record at 15 inches/second (ips), but the recorder began recording at 24 ips. Proper operation was regained by resending the commands. In another instance, the OPS 1 recorder was commanded to stop, but the record speed changed to 24 ips. The command was again resent to obtain desired operation. Operation of the OPS 1 recorder was maintained by resending commands.

The Ku-band antenna feed heater performance was erratic with temperatures dropping below the 0 °F limit (Flight Problem STS-32-24). Temperatures as low as -31 °F were observed.

One of the hand-held microphones provided poor quality communications (Flight Problem STS-32-28). The microphone was stowed for the remainder of the flight for postflight evaluation.

Six operational instrumentation anomalies were noted during the mission. These are discussed in the subsystem section of the report in which the instrumentation is located.

REMOTE MANIPULATOR SYSTEM

The RMS performance on six significant operations was nominal in that all planned major and minor objectives and development test objectives were accomplished. Major mission objectives were the capture, photographic survey and berthing of the LDEF in the payload bay. Minor planned objectives were the monitoring of the SYNCOM-IV-F5 perigee kick motor burn and accomplishment of two DTO's to gather data on RMS characteristics. DTO 0627 gathered arm stress gauge data during LDEF activities and DTO 0636 performed qualitative assessments of RMS brake fade phenomenon. Unplanned activities included the use of the arm for a waste water dump nozzle survey, thermal protection subsystem surveys, and for troubleshooting a suspected failed bit in the wrist-roll encoder.

On two occasions during the first use of the RMS, the crew heard an intermittent master alarm tone that was different from the nominal master alarm tone (Flight Problem STS-32-12). The tone could not be inhibited by depressing the master

alarm switch; consequently, the crew turned down the volume on the alarm to suppress the annoyance. The anomalous tone was compared to the RMS master alarm tone and was described as lower in volume, different in frequency, and continuous rather than pulsing at a 2 Hz rate. A caution and warning self test was conducted while the LDEF was grappled. This caused the RMS master alarm light to illuminate and the alarm tone was normal in volume and frequency and was pulsing at a 2 Hz rate. The false annunciation ceased without any crew action, and the alarm tone operated properly for the rest of the mission.

While cradling the arm following LDEF activities, a tachometer consistency check BITE error in the wrist-roll joint encoder occurred and a controller error (CNTL ERR) message was annunciated (Flight Problem STS-32-13). Further troubleshooting repeated the error annunciation. Evaluation of mission data indicated that as the wrist was rolled through approximately 175 degrees, the joint angle encoder exhibited inconsistent data. This anomaly did not impact the mission operations.

On three occasions during the mission, RMS brake slip annunciations were exhibited that indicated joint brake slippage was occurring, but the condition did not constrain RMS operations (Flight Problem STS-32-20). In each case, the RMS was latched in the manipulator retention latches and data shows that the joint angle was not changing.

FLIGHT CREW EQUIPMENT

The flight crew equipment operated satisfactorily except for three minor problems. During the scrubbed launch attempt, the MS-3 light was damaged when the crew ingressed the vehicle (Flight Problem STS-32-09a). The light was removed after the scrub, repaired and reinstalled for launch. A 20-ft CCTV camera cable could not be found by the crew during the mission. A re-evaluation of the stowage procedures will be made to determine why this cable was not stowed. While performing the flight day 10 post-sleep free fluid disposal IFM, there was no suction through the wand that connected into the waste water overboard dump line (Flight Problem STS-32-21). Postflight inspections of the wand and filter will be made to determine the cause of the blockage.

During postflight crew debriefings, the Pilot reported that his seat would drive up but not down (Flight Problem STS-32-27).

MECHANICAL SUBSYSTEMS

All remotely actuated mechanisms performed nominally throughout the mission. During berthing of the LDEF payload, the payload retention latch assemblies (PRLA's) ready-to-latch switches came on momentarily and then went off. This condition repeated several times for the various longeron latches. However, after the payload movement ceased, all ready-to-latch switches came on and the PRLA's were latched satisfactorily. This condition is to be expected with large payloads because of the RMS arm flexibility and the ready-to-latch spring forces.

The forward ET separation assembly centering right-hand stop bolt had a slight deformation, and marks on the bearing plate indicated movement (Flight Problem STS-32-26).

The landing and deceleration subsystem performance was satisfactory. The Orbiter landing weight of 228,335 lb was greater than any prior mission flown.

Deployment times for all landing gear were between 5.6 and 5.7 seconds, which was well within the requirement. Main gear touchdown occurred at a ground speed of 209 knots and 1870 feet from the threshold. Nose gear touchdown occurred at 162 knots ground speed with a pitch rate of 2.2 deg/sec. Orbiter data indicate that nose gear touchdown was 6611 feet from the runway threshold. Winds at landing were minimal at 4 to 5 knots.

Braking was initiated at 141 knots ground speed and 8096 feet from the runway threshold. Because of the Orbiter landing weight, brake energies were greater than usual. Brake energies on the left side, 39.4 and 36.8 million ft-lb, were higher than those on the right side, 26.4 and 31.3 million ft-lb. Deceleration was maintained between 5 and 7.5 ft/sec/sec for most of the braked roll. Wheel stop occurred at 12,563 ft from the runway threshold. Rollout distance was 10,164 ft. Temperatures as high as 270 °F were indicated on the left brake hydraulic actuators and 200 °F on the right actuators.

As of February 7, 1990, the brakes have not been inspected, but there are several indications that they may have sustained some heat damage. Postflight examination of the brakes revealed that many beryllium heat sink parts had turned blue. In addition, the tempilabels on the brake hydraulic actuators indicated higher-than-normal heating, and the brake energy calculations indicated levels commensurate with some damage, i.e., energy absorbed was greater than 25 million ft-lb. Based on the amount of energy dissipated by the brakes, brake removal prior to vehicle tow is a normal operation; however, this was not accomplished because of a ground support equipment (GSE) problem. The roll back did not result in any apparent additional damage.

Tire wear was nominal with the greater wear being exhibited by the tires on the left side. Postflight tire pressures indicated nominal leakage.

AERODYNAMICS

The Orbiter responded as expected throughout entry. All control surfaces responded properly and the angle-of-attack was as expected. Eight programmed test inputs (PTI's) were performed during entry and all appeared nominal.

THERMAL CONTROL SUBSYSTEM

Thermal control of the vehicle was satisfactory throughout the mission. The FES topping duct zone E (aft) system B heater failed off at approximately 14:18:22:00 G.m.t. (Flight Problem STS-32-14). Three other temperature sensor failures occurred, but these are discussed in the applicable subsystem section of the report.

AEROTHERMODYNAMICS/THERMAL PROTECTION SUBSYSTEM

The thermal protection subsystem (TPS) performance was nominal, based on structural temperature responses and some tile-surface temperature measurements. The overall boundary layer transition from laminar to turbulent flow was nominal and occurred between 1650 (right wing and aft of vehicle) and 1210 (front) seconds after entry interface. These boundary layer transition times are considered to be normal to late, based on previous flight experience and correlation with OV-102 roughness values.

The KSC Shuttle thermal imager (STI) was used to measure temperatures on the Orbiter about 25 minutes after landing. Temperatures of 150 °F were recorded at the nose cap reinforced carbon-carbon (RCC), 72 °F at the right-hand wing RCC panel 9, and 65 °F at the right-hand wing RCC panel 17.

The Orbiter thermal protection subsystem (TPS) sustained a total of 120 hits of which 111 were on the lower surface, excluding those on the base heat shield, and of these, 11 were significant. The heaviest concentration of hits (50) on the lower surface was aft and inboard of the liquid hydrogen umbilical door. This concentration of hits has been observed previously and is attributed to umbilical ice impacts during ET separation. No tile replacements are required because of the debris damage. The base heat shield peppering was above normal. The total hits on the lower surface is considered normal with the severity of the damage being less than average.

Overall, all RCC parts looked good. The experiment ports in the nose cap showed no evidence of degradation. The nose landing gear door thermal barrier and flow restrictors showed evidence of minor fraying. A 6-inch forward thermal barrier section had loose sleeving and a 6-inch section of center line thermal barrier was detached. One possible scrap was identified in the nose landing gear door because of a chipped corner. The ET door thermal barriers showed evidence of degradation. The right-hand forward thermal barrier was identified as scrap and will require replacement. The left-hand barrier showed minimal degradation and if compression tests are satisfactory, the barrier will fly again. The main landing gear door thermal barriers had minor tear areas, and there were no broken tiles on the doors. In the elevon cove area, evidence of outgassing was observed behind three trailing edge tiles. The engine-mounted heat shield thermal curtains were in excellent condition. On the upper surface, the outboard elevon tiles looked as bad as ever seen and the screed repair identified in the launch films and pad inspections was verified as missing. Also, a small section of debonded felt reusable surface insulation (FRSI) was identified on payload bay door 4. The elevon-elevon gap appeared better than normal with three frayed gap fillers on the right-hand side and seven on the left-hand side.

Orbiter window 3 was heavily hazed, window 4 was lightly hazed, and window 2 had two streaks on it. Samples were taken of the material on the windows, as well as the streaked wing panel sites and other selected damage sites.

PAYLOADS

A total of 10 payloads were involved in this mission. These included the SYNCOM-IV-F5 satellite, LDEF satellite, and 8 middeck payloads.

SYNCOM-IV-F5 SATELLITE

The SYNCOM-IV-F5 pin retraction was performed nominally and at the planned time. The fifth and final SYNCOM-IV-F5 payload was successfully deployed on the first opportunity on mission day 2 at 10:13:18:39 G.m.t. All post-deployment functions that were controlled within the spacecraft by the post-ejection sequencers occurred as scheduled, including perigee kick motor firing 45 minutes after deployment.

The liquid apogee motor was fired six times by ground command, and the satellite was placed in a geosynchronous orbit at approximately 182 °W. The UHF antennas were deployed, the launch locks were fired, the despun section was despun, and all spacecraft systems were checked out and are operating nominally. The payload communications channels are being activated and operationally verified. Approximately 60 percent of the communications channels were activated and were operating nominally when this report was written. Completed activation and checkout are anticipated by the end of February when the satellite will be ready for the Department of Defense to place in service.

LONG DURATION EXPOSURE FACILITY

The LDEF was successfully grappled at 12:15:16:05 G.m.t. (3 days 2 hours 41 minutes 05 seconds mission elapsed time). An extensive photographic survey of the entire LDEF was conducted while the satellite was still on the RMS arm. After completion of the photographic operations, the LDEF was berthed in the payload bay at 3 days 6 hours 35 minutes mission elapsed time (12:19:10:00 G.m.t.).

MIDDECK PAYLOADS

Preliminary data are provided on the 8 middeck payloads, and more detailed information will be provided by the sponsor of each payload.

The FEA completed approximately 85 percent of the assigned objectives. The crew reported a hairline crack at one end of the fluids experiment apparatus (FEA) ampule 4. After review of the IFM procedures for removal of the FEA ampule, the procedure was approved for implementation. This decision was based on the fact that the ampule glass was only cracked and would not fragment upon removal, and no toxic gas hazards exist. This procedure was performed and ampule 4 was removed, sealed in a plastic bag and stowed. FEA operations were re-initiated. At approximately 16:15:58 G.m.t., the FEA center front wall temperature sensor indicated that the wall exceeded the touch temperature limit of 113° F. The FEA deactivated itself as designed; however, the crew reported that the surface was not hot. The system was reactivated and operated satisfactorily for the remainder of the mission.

A temporary power loss occurred on the protein crystal growth (PCG) and the 4 °C sample may have been ruined, but the 22 °C sample should provide data. All IMAX camera film was exposed, but only 83 percent of the objectives were met because bad weather precluded photography of some sites. All 100 percent of the objectives of the mesoscale lightning experiment (MLE) and the LLL experiments were met. Initial indications are that 100 percent of the established goals for the characterization of neurospora circadian rhythms (CNCR) experiment were achieved. The Air Force Maui optical site calibration test (AMOS) failed to meet any of its objectives because of bad weather over the ground observation site. Over 100 percent of the American flight endocardiograph (AFE) experiment objectives were met as all five crew members participated in the experiment activities, whereas scans were planned for only two crew members.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

A total of 21 DTO's and 14 DSO's were assigned to this mission. Preliminary indications are that all but two of the DTO's were completed. Of the two that were not completed, one is no longer active, and the other required prelaunch measurements that were not taken.

DEVELOPMENT TEST OBJECTIVES

DTO 236 - Ascent Aerodynamic Distribution Loads Verification on OV-102 - The data were collected for this DTO and are being evaluated by the sponsor.

DTO 242 - Entry Aerodynamic Control Surfaces Test - This DTO was successfully accomplished during entry with all eight PTI's being performed. The data will be evaluated by the sponsor.

DTO 301 - Ascent Structural Capability Evaluation - The data were collected for this DTO and are being evaluated by the sponsor.

DTO 303 - RCC Life Evaluation - Although manifested, this DTO is no longer active and as a result, was not performed.

DTO 307 - Entry Structural Capability - Data were collected during entry for this DTO and will be evaluated by the sponsor.

DTO 311 - POGO Stability Performance - The data on longitudinal oscillations (POGO) were collected and are being evaluated by the sponsor.

DTO 312 - ET Thermal Protection System Performance - The crew photographically recorded the ET and the photographs are being evaluated by the sponsor.

DTO 318 - Direct Insertion ET Tracking for the Eastern Test Range - This DTO was not scheduled nor accomplished on this flight.

DTO 319 - Payload Low Frequency Environment - Data were collected for this DTO, but it requires a large soft-mounted payload, i.e., inertial upper stage/Tracking and Data Relay Satellite (TDRS), for acceptable data. Therefore, ascent data will not be useful with only the SYNCOM in the payload bay, nor will entry data with only the LDEF in the payload bay.

DTO 332 - Cabin Growth - Preflight measurements required for this DTO were not taken, consequently, the DTO cannot be successfully accomplished for this flight.

DTO 623 - Cabin Air Monitoring - Data collection was scheduled for each day of the flight and initial indications are that the data were collected.

DTO 627 - RMS Operating Loads and Data During LDEF Retrieve - This DTO was scheduled during the LDEF retrieval operations, and initial indications are that the data were collected.

DTO 636 - Direct Drive RMS Exercise - This DTO was scheduled at daily intervals following LDEF retrieval and was successfully completed. The data are being evaluated by the sponsor and the RMS community.

DTO 638 - Gas Bubbles in Potable Water - Water samples were collected for this DTO and are being evaluated by the sponsor.

DTO 703 - TDRS-to-TDRS Handover - This DTO was scheduled throughout the mission and the data are being evaluated by the sponsor.

DTO 784 - SGLS Navigation Certification - This DTO was manifested after the final Flight Requirements Document was published and was completed satisfactorily on flight days 5, 6, and 7. The data are being evaluated by the sponsor.

DTO 816 - Gravity Gradient Attitude Control - This DTO was successfully performed early in the mission and data are being evaluated by the sponsor.

DTO 823 - Additional Stowage Evaluation for Extended Duration Orbiter (EDO) - This DTO was completed and the data, in the form of crew reports, has been given to the sponsor for evaluation.

DTO 901 - OEX SILTS - Data were collected for this experiment and are being evaluated by the sponsor.

DTO 903 - OEX SEADS - Data were collected for this experiment and are being evaluated by the sponsor.

DTO 911 - OEX AIP - Data were collected for this experiment and are being evaluated by the sponsor.

DETAILED SUPPLEMENTARY OBJECTIVES

The DSO's included on this flight are as follows:

a. DSO 314 - Microgravity Acceleration Data Collection
b. DSO 457 - In-flight Salivary Pharmacokinetics
c. DSO 466 - Variations in Cardiovascular Performance
d. DSO 467 - Baroreflex Function in Weightlessness
e. DSO 471 - Airborne Particulate Matter in Orbiter Atmosphere
f. DSO 472 - Intraocular Pressure
g. DSO 473 - Delayed-Type Hypersensitivity
h. DSO 475 - Muscle Biopsy
i. DSO 476 - In-flight Aerobic Exercise
j. DSO 477 - Muscle Performance
k. DSO 478 - In-flight Lower Body Negative Pressure
l. DSO 901 - Documentary TV
m. DSO 902 - Documentary Motion Pictures
n. DSO 903 - Documentary Still Photography

TABLE I.- STS-32 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU activation	APU-1 GG chamber pressure	09:12:30:12.01
	APU-2 GG chamber pressure	09:12:30:13.55
	APU-3 GG chamber pressure	09:12:30:14.93
SRB HPU activation	LH HPU system A start command	09:12:34:32.30
	RH HPU system A start command	09:12:34:32.82
	LH HPU system B start command	09:12:34:32.30
	RH HPU system B start command	09:12:34:32.82
Main propulsion System start	Engine 3 start command to EIU	09:12:34:53.467
	Engine 2 start command to EIU	09:12:34:53.571
	Engine 1 start command to EIU	09:12:34:53.702
SRB ignition command (lift-off)	SRB ignition command to SRB	09:12:35.00.017
Throttle up to 104 percent thrust	Engine 3 command accepted	09:12:35:04:068
	Engine 2 command accepted	09:12:35:04.051
	Engine 1 command accepted	09:12:35:04.063
Throttle down to 102 percent thrust	Engine 3 command accepted	09:12:35:17.988
	Engine 2 command accepted	09:12:35:17.972
	Engine 1 command accepted	09:12:35:17.983
Throttle down to 65 percent thrust	Engine 3 command accepted	09:12:35:27.909
	Engine 2 command accepted	09:12:35:27.892
	Engine 1 command accepted	09:12:35:27.903
Maximum dynamic pressure (q)	Derived ascent dynamic pressure	09:12:35:52.1
Throttle up to 104 percent thrust	Engine 3 command accepted	09:12:35:58.909
	Engine 2 command accepted	09:12:35:58.773
	Engine 1 command accepted	09:12:35:58.784
Both SRM's chamber pressure at 50 psi	LH SRM chamber pressure mid-range select	09:12:36:59.53
	RH SRM chamber pressure mid-range select	09:12:36:59.25
End SRM action	LH SRM chamber pressure mid-range select	09:12:37:02.02
	RH SRM chamber pressure mid-range select	09:12:37:01:42
SRB separation command	SRB separation command flag	09:12:37:04.09
SRB physical separation	SRB physical separation	
	LH APU A turbine speed LOS*	09:12:37:05.14
	LH APU B turbine speed LOS*	09:12:37:05.18
	RH APU A turbine speed LOS*	09:12:37:05.18
	RH APU B turbine speed LOS*	09:12:37:05.14
Throttle down for 3g acceleration	Engine 3 command accepted	09:12:42:31.893
	Engine 2 command accepted	09:12:42:31.905
	Engine 1 command accepted	09:12:42:31.911
3g acceleration	Total load factor	09:12:42:38.5
MECO	MECO command flag	09:12:43:32.7
	MECO confirm flag	09:12:43:33.
ET separation	ET separation command flag	09:12:43:50.7

* = loss of signal

TABLE I.- CONTINUED

Event	Description	Actual time, G.m.t.
OMS-1 ignition	Left engine bi-prop valve position	None required/ Direct insertion
APU deactivation	APU-1 GG chamber pressure	09:12:49:33.32
	APU-2 GG chamber pressure	09:12:49:35.18
	APU-3 GG chamber pressure	09:12:49:36.74
OMS-2 ignition	Left engine bi-prop valve position	09:13:15:25.6
	Right engine bi-prop valve position	09:13:15:25:6
OMS-2 cutoff	Left engine bi-prop valve position	09:13:17:45.6
	Right engine bi-prop valve position	09:13:17:45.6
OMS-3 ignition (NC2 maneuver)	Right engine bi-prop valve position	10:09:00:17.4
OMS-3 cutoff	Right engine bi-prop valve position	10:09:00:26.2
SYNCOM-IV-F5 deploy	Voice call	10:13:18:39
OMS-4 ignition (Separation)	Right engine bi-prop valve position	10:13:33:37.2
OMS-4 cutoff	Right engine bi-prop valve position	10:13:33:58.6
SYNCOM-IV-F5 burn	Voice call	10:14:03:48
OMS-5 ignition (NH-1 maneuver)	Left engine bi-prop valve position	10:17:23:13.0
OMS-5 cutoff	Left engine bi-prop valve position	10:17:23:34.4
OMS-6 ignition	Left engine bi-prop valve position	11:14:37:42.6
OMS-6 cutoff	Left engine bi-prop valve position	11:14:37:51.2
OMS-7 ignition	Right engine bi-prop valve position	11:15:14:14.4
OMS-7 cutoff	Right engine bi-prop valve position	11:15:14:25.6
LDEF capture	Voice call	12:15:16:05
Flight control system checkout		
APU start	APU-1 GG chamber pressure	18:05:48:08.43
APU stop	APU-1 GG chamber pressure	18:05 54:28.16
APU activation for entry	APU-2 GG chamber pressure	20:08:25:31.62
	APU-1 GG chamber pressure	20:08:51:37.24
	APU-3 GG chamber pressure	20:08:51:38.87
Deorbit maneuver ignition	Left engine bi-prop valve position	20:08:30:22.1
	Right engine bi-prop valve position	20:08:30:22:1

TABLE I.- CONCLUDED

Event	Description	Actual time, G.m.t.
Deorbit maneuver cutoff	Left engine bi-prop valve position	20:08:35:21.6* (Planned)
	Right engine bi-prop valve position	20:08:35:21.6* (Planned)
Entry interface (400k)	Current orbital altitude above reference ellipsoid	20:09:04:26.6
Blackout end	Data locked at high sample rate	No blackout because of TDRS
Terminal area energy management	Major mode change (305)	20:09:29:27.9
Main landing gear contact	RH MLG tire pressure 1	20:09:35:36.15
	LH MLG tire pressure 1	20:09:35:37.12
Main landing gear weight on wheels	LH MLG weight on wheels	20:09:35:36.22
	RH MLG weight on wheels	20:09:35:37.30
Nose landing gear contact	NLG tire pressure 1	20:09:35:51.5
Wheels stop	Velocity with respect to runway	20:09:36:39.3
APU deactivation	APU-1 GG chamber pressure	20:09:52:53.56
	APU-2 GG chamber pressure	20:09:52:56.21
	APU-3 GG chamber pressure	20:09:52:57.41

Note:

* Data loss occurred before engine cutoff

TABLE II.- STS-32 PROBLEM TRACKING SUMMARY

Number	Title	Reference	Comments
STS-32-01	FM System 1 Transmitter Failure	09:12:35:03 G.m.t. PR-COM-2-10-0136 IM 32RF01	FM transmitter 1 RF power output dropped to zero watts during early powered flight. Transmitter removed and replaced on 2/1.
STS-32-02	APU 3 Lubrication Oil Outlet Pressure High	09:12:36 G.m.t. IPR 32-V-0228 IM 32RF02	APU 3 experienced slightly high lubrication oil outlet pressure (approximately 90 psi, should be about 55 psi) during ascent. Returned to normal at full operating temperatures. Contingency OMRSD implemented during OMI 1078.
STS-32-03	Operational instrumentation failures		
	a) R OMS Helium Pressure 2 Off-Scale Low	a) 09:13:15 G.m.t. IM 32RF03 IPR-35-V-0030 (deferred)	a) Right OMS helium pressure 2 (V43P5122C) failed off-scale low. Fly as is
	b) APU 3 EGT 2 Failed	b) 09:12:32 G,m.t. IM 32RF04 PR-APU-2-10-188	b) APU 3 EGT 2 operation was erratic during ascent and sensor failed during entry. Removed and replaced on 2/7.
	c) FCL 2 Evaporator Outlet Temperature Had Slow Response	c) 09:12:44 G.m.t. IM 32RF05 PR ECL-2-10-558	c) FCL 2 evaporator outlet temperature had a slow response (V63T1407A). Troubleshooting found sensor debond.
	d) APU 2 GG/Injector Temperature Miscompare	d) 10:12:26 G.m.t. IM 32RF10 IPR-35-V-0014	d) APU 2 gas generator/injector temperature miscompare (V46T0222A/ V46T0274A). Troubleshooting could not reproduce problem. Further troubleshooting with breakout box is continuing.
	e) Right OMS Fuel Pressure Transducer Erratic	e) 14:19:10 G.m.t. IM 32RF14 IPR-35-V-0031 (deferred)	e) Right OMS fuel pressure transducer (V43P5321C) was erratic. Fly as as
	f) Supply Water Tank B Quantity Transducer Transients	f) 17:01:22 G.m.t. IM 32RF19 PR-ECL-2-10-561	f) Numerous off-scale low transients (Also occurred on STS-28) were noted. Troubleshooting and remove and replace, if required
	g) APU 2 EGT 2 Erratic Operation	g)IM 32RF23 PR-APU-2-10-188	g) APU 2 EGT 2 failed during entry. Removed and replaced on 2/7.
STS-32-04	Right OMS No-Back Device Moved During Ascent	09:12:36 G.m.t. IM 32RF06	The right OMS no-back device moved more than 0.1 degree during ascent. Moved 0.098 degree on a previous flight. Assessed during entry and movement was within limits (0.048 degree). RCN in process to change limit to 0.2 degree. Fly as is
STS-32-05	TAGS Paper Jammed	10:08:11 G.m.t. 10:19:20 G.m.t. 10:19:34 G.m.t. PR-COM-2-10-0137	The TAGS paper jammed several times during the mission. IFM sent on flight day 5 which cleared the jam and no more occurred after performing this procedure. TAGS returned to JSC for test on 2/8

TABLE II.- STS-32 PROBLEM TRACKING SUMMARY

Number	Title	Reference	Comments
STS-32-06	Gaseous oxygen flow control valve 2 open cycle sluggish	09:12:36 G.m.t. IM 32RF07 J3188	The engine 2 flow control valve displayed a sluggish opening cycle (was 0.75 second; should be 0.2 to 0.4 second) on the first de-energization cycle. All other engine 2 flow control valves were nominal. KSC to removed and replaced the valve and sent to RI/Downey for inspection of poppets. Blowdown decision on 2/9
STS-32-07	Humidity Separator Water Bypass Anomalies		
	a) Humidity Separator B	a) 11:09:11 G.m.t. IM 32RF08 PR ECL-2-10-559	a) Free water was observed exiting from humidity separator B. Crew switched to humidity separator A. Free water cleanup IFM procedure performed. Humidity separator off for ferry flight
	b) Humidity Separator A	B) 14:20:12 G.m.t. IM 32RF15	b) Similar to humidity separator B problem. Crew cleaned up about 2.5 cups of water. Crew reported water trickling out of humidity separator A on other occasions later in the mission. Humidity separator package removed 1/31 and inspection performed on 2/3. Some white residue found on heat exchanger outlet
STS-32-08	Forward DAP B Select Switch Contact A Failure	10:13:09 G.m.t. IM 32RF09 IPR-35-V-0013	Contact A closed 2 seconds earlier than contact B, and this caused the RM to declare contact A failed and deselected it. Same contact had same problem on STS-4 and STS-9. Fly as is
STS-32-09	Government Furnished Equipment: MS-3 Light Damaged During Crew Ingress	Prelaunch for Scrubbed Launch Attempt	Clamp failed: two guide rods were bent. Clamp assembly repaired and re-installed prior to launch on January 9, 1990. Removed and sent to JSC
STS-32-10	Forward Bulkhead Flood Light Inoperative	13:13:32:21 G.m.t. IM 32RF11	Repeat attempt to power the light not successful. Ground controllers saw the RPC trip and suspect short in floodlight. Troubleshooting isolated the failure to floodlight electronics assembly which was removed and replaced
STS-32-11	CCTV Anomalies:		
	a) CCTV Camera A Had Spot In Field Of View	a) 12:17:56 G.m.t. (GFE)	a) CCTV camera A has a spot near the center of the field of view. Consistent with burned spot on the image tube. Fly as is
	b) RMS Elbow Camera Color Wheel Failed	b) 14:00:46 G.m.t. (GFE)	b) Camera color wheel failure manifested itself as a line across picture. This is the line between color filters on the wheel. Removed camera and sent to vendor on 1/31
	c) CCTV Camera C Poor Picture	c) 14:01:20 G.m.t. (GFE)	c) Picture is good in sunlight and degrades in darkness. Removed and sent to vendor
	d) CCTV Camera D Had Spot in Field of View	d) 14:11:35 G.m.t. (GFE)	d) Camera D had a spot on the right center portion of the picture. Fly as is

TABLE II.- STS-32 PROBLEM TRACKING SUMMARY

Number	Title	Reference	Comments
STS-32-12	RMS Master Alarm Tone Generator Intermittent Unknown Annunciation	12:15:00 G.m.t. (GFE) TPS-RMS-201-017	Tone annunciated on two occasions with no associated lights or messages. Tone could not be inhibited by depressing master alarm PBI. Removed and sent D&C panel to vendor for repair on 2/7.
STS-32-13	RMS "CNTL ERR" Message	12:21:15 G.m.t. (GFE)	"CNTL ERR" message annunciated as wrist was rolled through approximately 175 degrees. Occurred twice. Suspect bad bit in wrist encoder. RMS removed and sent to SPAR for troubleshooting and repair on 2/6
STS-32-14	FES Topping Duct B String Heater Failure (V63T1802A)	14:19:28 G.m.t. IM 32RF12 IPR 35-V-0016	After activation of FES top duct heater B, the aft duct temperature did not increase. Standard troubleshooting procedures in work. Suspect MPCA or wiring. Heater check okay.
STS-32-15	IMU 1 RM Failed (Transient Y-Axis Accelerometer Bias)	15:01:42 G.m.t. IM 32RF13 PR-GNC-2-10-0058	Multiple Y-axis velocity transients. IMU manually reselected. Remove and replace with serial number 25, but will not install new unit until just before the hangar calibration. Send removed unit to JSC
STS-32-16	Hydraulic systems 1 and 2 Circulation Pump Unloader Valves Excessive Leakage	10:09:16 G.m.t. IM 32RF16	Hydraulic systems 1 and 2 circulation pump unloader valve leaked excessively once the accumulator pressure fell below approximately 2300 psia. Normal checkout will be performed during OMI V1010 on 3/10
STS-32-17	Water Spray Boiler System 2 and 3 Showed Excessive Regulator Pressure Decay	11:10:04 G.m.t. IM 32RF17	Gaseous nitrogen regulator pressure on water spray boilers 2 and 3 have indicated decay rates of approximately 0.11 psi/hr over a 16-hour period. Decay rate decreased to zero late in the mission. Chit J3190 to offload water and cycle relief valve 3 or 4 times approved. GN2 24-hour decay check on system 2 showed no leaks. System 3 checks in work
STS-32-18	Multiple S-band Dropouts	IM 32RF18 IPR 35-V-0017	Intermittent long-duration forward link dropouts occurred throughout the mission. Suspect lower right antenna RF path. Chit for special tests approved. Able to recreate dropouts
STS-32-19	Smoke Detector 3A Transient Alarm and Associated Lights	17:16:08:36 G.m.t. IM 32RF20 PR ECL-2-10-560	Smoke detector 3A alarm reset itself after approximately 10 seconds. Master alarm manually reset. Alarm 3A and 3B self-test showed system operational. Removed and replaced
STS-32-20	RMS Brake Slip Annunciation	09:18:13 G.m.t. (GFE)	False alarm generated by software. Program note or software fix required. No KSC action required.

TABLE II.- STS-32 PROBLEM TRACKING SUMMARY

Number	Title	Reference	Comments
STS-32-21	Waste Water Dump Line/ Nozzle Blockage	18:04:35 G.m.t. IM 32RF21	During flight day 10 post-sleep free fluid disposal activities, no suction was present through the wand. Later a waste water tank dump was also unsuccessful. Troubleshooting determined that no icing existed in waste dump line. The blockage was suspected to be in the waste water dump line or nozzle. Charred material around urine dump nozzle face. Orifice was clear. Sample taken indicates some potassium amongst the charred material, everything else nominal. "Mucky Junk" flushed from dump line. Valve and nozzle removed and replaced
STS-32-22	Backup Flight System GPC Errors (I/O Term B)	20:06:16 G.m.t. IM 32RF22)	The general purpose computer (GPC) in which the backup flight system (BFS) software was resident registered numerous GPC error code 41's (illegal engage/IO term B) The error was the result of the BFS detecting no IO terminal B discrete when the engage discretes are not present. The error was logged 43 times before the GPC was halted. As a result, the BFS was moved from GPC 5 to GPC 2 and reinitialized. The GPC set was restrung and GPC 5 was powered off for the remainder of the mission. GPC 5 not to be powered on in the vehicle. Able to recreate the problem; however, when breakout boxes installed, problem disappeared
STS-32-23	WSB 3 Controller A Over-Cooling	20:09:15 G.m.t. IM 32RF24	WSB 3 went to the heat exchanger mode early and dumped excessive water while operating on controller A. Switched to controller B and system operated normally. Troubleshooting shows controller A operating normally
STS-32-24	Ku-band Antenna Feed Heater Erratic	IM 32RF25	Ku-band antenna feed temperature (74T2963A) dropped below the temperature lower limit of 0 °F. Temperatures as low as -31 °F were seen. Ku-band removed and replaced 2/7
STS-32-25	MPS Liquid Hydrogen Fill and Drain (Outboard) Relief Valve Leak (PV11)	Postflight Inspection IM 32RF26	MPS relief valve (PV11) had a blowing leak that was observed during the postlanding inspection. Leak was heard and felt at the 6:30 o'clock position on the valve. Helium tank pressure decrease confirmed the leak. PV11 removed and replaced. Leak check revealed another leak at PV05
STS-32-26	Forward ET Separation Assembly Centering Mechanism Right Hand Stop Bolt Depressed	Postflight Inspection IM 32RF27	Forward right-hand ET separation centering stop mechanism bolt was compressed. Scratches on bearing plate indicate movement. Preliminary indications are that this is normal for the expected load on the bolt

TABLE II.- STS-32 PROBLEM TRACKING SUMMARY

Number	Title	Reference	Comments
STS-32-27	Pilot Seat Will Not Drive Down	During Entry	Pilot seat would drive up, but not down. Forward and back drive capability not tested. Try to duplicate problem in 1-g trainer at JSC. Ground tests show seat operating nominally
STS-32-28	Hand-held Microphone Communications Degraded	On-orbit	Crew noticed ground consistently said that voice was "ratty" when one of the three hand-held microphones was used. This microphone was stowed for the remainder of the flight. Shipped to JSC in locker MA16G
STS-32-29	Orbiter Gas Sampler System Assembly on 50-1 Access Door (port side) Failed To Operate	During Ascent PR PV6-151/63-Z	The pyrotechnics in all three bottles failed to fire. Suspect battery or electronics problem. KSC troubleshooting found no problem and assembly shipped to JSC on 2/1

NASA Headquarters
QP/N. R. Schulze
QT/M. Greenfield
LB-4/G. L. Roth
MA/R. L. Crippen
MO/G. Krier
MOJ/C. Perry
ML/W. Hamby
MES/N. Frandsen

Goddard Space Flt Ctr
300/R. L. Bauman
700/J. R. Busse
710/T. E. Huber
730/E. I. Powers
730.1/J. P. Young
400/D. W. Harris
400/P. T. Burr
410/J. Barrowman (6)
302/W. F. Bangs
313/R. Marriott

KSC
NWSI-D/Respository (25)
MK/B. H. Shaw

MSFC
CN22D/Respository (30)
EP51/J. Redus (5)
EL74/P. Hoag (5)
FA51/S. P. Sauchier
JA01/J. A. Downey
SA12/O. E. Henson

Langley Research Center
Technical Library/
Mail Stop 185

Rockwell-Downey
AD75/Data Management (55)

Rockwell-Houston
RS12/A. Coutret (10)
RS12/L. A. Jared
ZC01/D. McCormack
R16G/J. Woodard
R16G/R. Pechacek

JSC
AA/A. Cohen
AC/D. A. Nebrig
AC5/J. W. Young
AP3/J. E. Riley (4)
AP4/B. L. Dean (3)
BL/W. L. Draper
BY4/History Office (2)
CA/D. R. Puddy
CA4/R. Filler
CB/D. Brandenstein (10)
CB/K. Colgan
DA/Library
DA2/T. W. Holloway
DA3/S. G. Bales
DA8/R. Legler
DA8/Library
DF/J. Knight
DF7/P. Cerna
DF72/Q. Carelock
DF75/D. Nelson
DG/R. K. Holkan
DH4/R. D. Snyder
DH411/E. B. Pippert
DH4/J. F. Whitely
DH45/M. LeBlanc
DM/J. C. Harpold
DM/C. F. Deiterich
EA/H. O. Pohl
EC/W. W. Guy
EC/F. H. Samonski
EC2/D. F. Hughes
EC3/M. Rodriguez
EC4/L. O. Casey
EC6/E. Winkler
EC6/J. W. McBarron (5)
EC6/D. M. Hoy
ED3/R. Barton
EE/J. H. Johnson
EE2/H. A. Vang
EE7/O. L. Schmidt
EE7/J. C. Dallas
EF/I. Burtzlaff
EF3/J. A. Lawrence
EH/K. J. Cox
EH/P. C. Kramer
EH2/L. B. McWhorter
EH2/J. E. Yeo
EH4/W. N. Trahan
EP/C. A. Vaughn
EP2/H. J. Brasseaux
EP2/L. Jenkins
EP5/C. R. Gibson
EP5/N. Faget
ES/D. C. Wade
ES/W. G. McMullen (2)
ES3/J. A. Smith
ES3/C. R. Ortiz
ES3/L. D. Palmer
ES3/Y. C. Chang
ES3/P. Serna
ES6/C. W. Norris (2)
FA/R. L. Berry
FA/J. R. Garman
FD3/S. Morris
FM/C. A. Graves, Jr. (8)
FM/E. R. Schiesser
FR/E. S. Chevers
FR/SSD Library
FS/J. W. Seyl (2)
GA/L. S. Nicholson
GA/J. H. Greene
GM/D. C. Schultz
JL4/R. L. Squires
JM2/Library (3)
MJ/T. R. Loe (3)
NA/C. S. Harlan
NB/D. L. Duston
ND/M. C. Perry
NS/D. W. Whittle
SA/C. L. Huntoon
SD/S. L. Pool
SD2/J. R. Davis
SD24/D. A. Rushing
SD4/N. Cintron
SD5/J. Charles
SE/J. H. Langford
SN3/D. Pitts
SP/C. D. Perner (5)
TA/C. H. Lambert
TC3/P. S. Jaschke
TC3/J. Lowe
TJ/L. E. Bell
TJ2/G. W. Sandars
TM2/J. Bates
VA/D. M. Germany
VA/J. C. Boykin
VA/G. A. Coultas
VE/P. C. Glynn
VE3/M. C. Coody
VE4/W. H. Taylor
VF/J. E. Mechelay
VF2/W. J. Gaylor
VF2/J. W. Mistrot
VF2/B. Johnson
VF2/C. Critzos
VF3/D. W. Camp
VF3/R. W. Fricke (25)
VF3/T. Welch
VF3/M. Engle
VF4/E. R. Hischke
VF5/S. M. Andrich
VG/F. Littleton
VK/J. Presnell
VP/C. McCullough (3)
VP12/D. Fitts
VR/D. D. Ewart
WA/L. G. Williams
WC/L. D. Austin
WE/R. D. White
WG/W. J. Moon
C07/LESC Library
ZR/Lt. Col. J. McLeroy
ZR12/J. A. Yannie
BARR/R. Culpepper
BARR/H. Jones
BARR/R. Hennan
ECHS/Hamilton Standard

External Distribution
Mr. Willis M. Hawkins
Senior Advisor
Lockheed Corporation
P. O. Box 551
Burbank, CA 91520

Russell A. Larson
Mail Stop 4A
Charles Stark Draper Lab., Inc.
555 Technology Square
Cambridge, MA 02139

Lt. Gen. Leighton I. Davis USAF (Ret.)
729 Stagecoach Road,
Four Hills
Albuquerque, NM 87123

Mr. Ira Grant Hedrick
Presidential Assistant for Corporate Technology
Grumman Aerospace Corp
Bethpage, NY 11714

Dr. Seymour C. Himmel
12700 Lake Avenue, #1501
Lakewood, OH 44107

Mr. John F. McDonald
Vice President-Technical Services
TigerAir, Inc.
3000 North Claybourn Ave
Burbank, CA 91505

Dr. John G. Stewart
Manager, Office of Planning and Budget
TVA E6C9
400 Commerce Avenue
Knoxville, TN 37902

TRW
Houston, TX 77058
Attn: C. Peterson/H5

R. Birman
General Electric Co.
Space Division
P. O. Box 8555
Philadelphia, PA 19101

R. Hoey
6510 Test Wing/TEG/236
Edwards AFB, CA 93523

Headquarters, Space Div
Attn.: SSD/CLP
Los Angeles AF Station
P. O. Box 92960
Worldway Postal Center
Los Angeles, CA 90009

John Williams
1995 Ferndale Place
Thousands Oaks, CA 91360

C. Woodland, Prog. Mgr.
SPAR Aerospace Limited
1235 Ormond Drive
Weston, Ontario
Canada, M9L 2W7

Darryl Strickland
P. O. Box 1440
North Highlands, CA
95660-8940

A. S. Jones (2)
SPAR Aerospace Limited
1235 Ormont Dr.
Weston, Ontario,
Canada M9L 2W7

J. Middleton
SPAR Aerospace Limited
1700 Ormont Drive
Weston, Ontario,
Canada M9L 2W7

N. Parmet
5907 Sunrise Drive
Fairway, Kansas 66205

R. Peterson
Mail Stop 351-4A
Honeywell Inc.
13350 Hwy 19
Clearwater, FL 34624

AFOTEC/OL-BF (2)
Cape Canaveral AFS, FL 329

Aerospace Corporation
P. O. Box 92957
Los Angeles, CA 90009
Attn: W. Smith, M5/619

McDonnell Douglas-Houston
D2/M. D. Pipher
T3A/A. D. Hockenbury

D. Molgaard
2525 Bay Area Blvd.
Suite 620
Houston, TX 77058

L. R. Adkins/IBM Bldg
Mail Code 6206
3700 Bay Area Boulevard
Houston, TX 77058

James R. Womack
JPL/233-307
4800 Oak Grove Dr
Pasadena, CA 91109

T. Myers, Sys Tech, Inc.
13766 So. Hawthorne Blvd.
Hawthorne, CA 90250

Mr. James V. Zimmerman
NASA European Rep
c/o American Embassy
APO New York, NY 09777

J. R. Cretcher 6223/577W (2
Lockheed Astronautic Div
Astronautic Engineering
Information Center
P. O. Box 3504
Sunnyvale, CA 94088

Commanding General
U. S. Army Logistics Center
Attn: ATCL-PS/Col. Senegal
Ft. Lee, VA 238001-6000

Capt. J. Behling
6555 ASTG/SMSP
Cape Canaveral AFS, FL. 329

Notify VF2/R. W. Fricke (FTS-525-3313) of any correction, additions, or deletions to this list.